



(11) **EP 1 861 618 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
18.07.2012 Bulletin 2012/29

(21) Application number: **06710079.2**

(22) Date of filing: **15.03.2006**

(51) Int Cl.:
F03B 13/18^(2006.01)

(86) International application number:
PCT/GB2006/000906

(87) International publication number:
WO 2006/100436 (28.09.2006 Gazette 2006/39)

(54) **APPARATUS AND CONTROL SYSTEM FOR GENERATING POWER FROM WAVE ENERGY**
VORRICHTUNG UND STEUERSYSTEM ZUR STROMERZEUGUNG AUS WELLENENERGIE
APPAREIL ET SYSTEME DE COMMANDE POUR GENERER DE L'ENERGIE A PARTIR DE L'ENERGIE DES VAGUES

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR

(30) Priority: **23.03.2005 GB 0505906**

(43) Date of publication of application:
05.12.2007 Bulletin 2007/49

(60) Divisional application:
10010996.6 / 2 292 924

(73) Proprietor: **Aquamarine Power Limited Glasgow G2 5NJ (GB)**

(72) Inventors:
• **THOMSON, Allan Robert Inverness IV1 2ER (GB)**
• **WHITTAKER, Trevor John Northern Ireland BT23 SYT (GB)**
• **CROWLEY, Michael David Gloucestershire GL2 7E2 (GB)**

(74) Representative: **Newell, Campbell Marks & Clerk LLP Aurora 120 Bothwell Street Glasgow G2 7JS (GB)**

(56) References cited:
WO-A-98/17911 WO-A-2004/007953
WO-A-2004/097212 WO-A1-03/036081
US-A- 4 371 788 US-A- 4 384 456

- **PATENT ABSTRACTS OF JAPAN vol. 017, no. 229 (M-1406), 11 May 1993 (1993-05-11) - & JP 04 358769 A (NAGASHIMA KOUSAN KK), 11 December 1992 (1992-12-11)**
- **PATENT ABSTRACTS OF JAPAN vol. 007, no. 269 (M-259), 30 November 1983 (1983-11-30) & JP 58 148279 A (SANWA TETSUKI KK), 3 September 1983 (1983-09-03)**

EP 1 861 618 B1

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

[0001] The present invention relates to an apparatus for generating power by extracting energy from waves. A control system for use therewith is also described.

[0002] Concerns about global warming and environmental pollution caused by the use of fossil fuels in energy generation has resulted in a move towards so-called 'green' energy sources, or renewable energy sources such as tidal movement, wave power and wind power.

[0003] It has long been recognised that the waves in the sea and other bodies of water provide a vast and substantially untapped quantity of energy and many inventions have been made with the goal of achieving the aim of extracting power from the sea. One type of device for recovering wave energy is a downwards hanging flap or a pendulum which is reciprocally swung or rocked by waves in a caisson and the reciprocal movement of the pendulum is converted to electric power. Such an arrangement is described in US Patent No. 4,580,400. An alternative arrangement is a seabed mounted or supported structure having a hinged lever attached to a panel for reciprocation motion and such an arrangement is described in International Publication No. WO 2004/007953 A1. This arrangement is used in relatively deep water, at a preferred depth of about $L/2$, where L is the wavelength of the waves expected at the location of use. A somewhat similar arrangement is disclosed in WO 03/036081 where a reciprocating body is situated entirely underwater in a water basin of intermediate depth. In contrast an alternative device described in WO 98/17911 is for use in shallow waters. It makes use of the "translation" waves formed where deep-water waves break or are broken as they run up the seashore. The device has a flap, which is pushed backwards by the translation waves and returns to the upright between each wave impulse using springs.

[0004] US 4,371,788 describes a flexible flap supported on a frame which moves backwards and forwards in response to wave motion. JP 04358769 discloses a flap oscillating in response to wave motion which is supplied with a sliding portion including a float which extends as the water depths increase.

[0005] There are numerous other examples of other wave power generating apparatus. Whilst such devices have been previously proposed they have fundamental failings for various reasons including lack of robustness in what is a very hostile environment; the need to 'over engineer' devices so as to make them suitable for use in hostile environments with consequent cost and maintenance implications; the need to utilise substantial anchorage devices for holding such apparatus in a secure manner on the seabed; and relatively substantial maintenance and repair costs for such devices.

[0006] In particular, previously proposed devices have generally been inefficient. The quantity of power captured from the incident waves has tended to be low and the subsequent conversion of the captured power into elec-

tricity poor. The devices have tended to produce power unevenly with large 'spikes' in the output, making it difficult to provide a smooth power output suitable for delivery into an electrical grid system.

[0007] It is an object of the present invention to avoid or minimise one or more of the foregoing disadvantages.

[0008] The present invention provides a wave energy conversion device, for use in relatively shallow water, comprising: a base portion formed and arranged for anchoring to the bed of a body of water in use of the device; an upstanding flap portion pivotally connected to said base portion, said flap portion being biased to the vertical in use and formed and arranged to oscillate, in use, backwards and forwards about the vertical in response to wave motion acting on faces of the flap portion; and power extraction means for extracting energy from the movement of the flap portion; characterised in that said device is formed and arranged so that when the base portion is anchored to the bed of a body of water with the flap portion facing the wave motion, the base portion and the flap portion extend vertically through at least the entire depth of the water, to present a substantially continuous surface to the wave motion throughout the full depth of water from the wave crest to the sea bed, and said flap portion is sufficiently buoyant in water so as to be biased to the vertical in use and has a high centre of buoyancy and a low centre of mass.

[0009] It will be understood that although the flap portion is biased to the vertical, in some (weak) sea states, or where the wave motion is not regular, the flap portion may from time to time not oscillate through the vertical on every wave motion.

[0010] By presenting a substantially continuous surface to the wave motion throughout the depth of the water (the 'water column'), the flap portion of the invention can efficiently capture the maximum amount of energy from the wave motion prevailing at a given location.

[0011] Relatively small gaps above, below or in the flap portion, can have a deleterious effect on the power capture factor of a device of the invention. The power capture is defined as the ratio of the power captured by a device to the power available from the waves incident on the device.

[0012] For example, a gap between the base portion and the flap portion or between the flap portion and the seabed, through which wave motion can pass, can cause significant power capture losses. The inventors have identified that a loss of up to 30% in power capture can occur by having a gap between the base portion and the flap portion as discussed hereafter with reference to experimental results relating to specific embodiments of the invention. Accordingly it is preferred that the base portion and the flap portion are formed and arranged to operate substantially without a gap between them. Similarly the inventors have identified that if the flap portion does not extend up to the water surface in the wave crest then losses occur over the top of the flap. Relatively small holes or passages through the flap portion have a similar

effect. Thus preferably the flap portion is formed and arranged to extend up through the surface of the water i.e. the flap pierces the water surface under normal calm conditions.

[0013] Preferably the flap portion is formed and arranged with the base portion to account for changes in the depth of the water at a given location caused by tidal change and also to account for the expected variations in wave height i.e. the flap portion and the base are sized so that the flap will pierce the water surface at all expected tide levels and sea states. This allows capture of wave energy throughout the full depth of the water ie the water column, including at the surface in all but the most exceptional (high) sea states. Providing some 'freeboard' to the flap, a portion projecting above the water surface, makes allowance for tidal and wave variation.

[0014] Preferably the device is formed and arranged for location at a mean water depth of between 6 to 20 metres, desirably between 8 and 16 metres. At these shallower depths, the available surge wave energy, in typical sea locations at least, is substantially greater than in the deeper waters often used by other wave energy conversion devices. At the same time there remains sufficient depth to allow for a flap portion of sufficient height to have an oscillation that extracts energy efficiently from the wave motion. For example, experimental results modelling the power extraction capability of a 12m by 12m flap portion operating at mean water depths of 22m and 10m shows the benefit of operating at the shallower depth. The power capture at 10m water depth was from 1.4 to 2.2 times the power capture at 22m, depending on the sea state being studied. This increase is attributed to the increase in horizontal wave force at the shallower depth combined with the effect of the flap capturing energy throughout the full depth of the water when at 10m. At shallower depths breaking waves and the loss of volumetric displacement by a shorter flap portion reduces the energy available for capture and the system efficiency is substantially reduced.

[0015] Advantageously the flap portion has a generally rectangular form. Other flap shapes are possible. The rectangular form may be of a generally stiffened flat plate, however, depending on the construction method of the flap portion other generally rectangular bodies can be made. If the flap portion is composed of a flat plate or flat plates, it is preferred that they are made of a composite, reinforced structure. This improves the ability of the flap portion to withstand the forces imposed by the wave motion. For example, the flap portion may be constructed of plates comprising two outer skins of steel plate with steel reinforcing bars placed at regular intervals between them, and welded to the inner surface of each plate. In use for a flap portion the spacing between the reinforcing bars and the outer skins can be filled with a material such as concrete to provide added strength and adjust buoyancy. The flap portion may be constructed of modular components. For example the flap may comprise sections of generally circular in section piping or tubing ar-

ranged in a plane, by stacking horizontally or vertically parallel and adjacent each other, to give a generally rectangular form to the flap. Advantageously where the tubing is stacked horizontally to form the flap portion the sections of piping or tubing may be of different diameters. A flap portion with smaller sections of tubing near the base (pivot) and larger sections of tubing near towards the top edge has some advantages with regard to the control of biasing and the robustness of the flap portion as discussed hereafter.

[0016] A flap portion constructed of pipe sections in this manner has a number of advantages. The 'modular' construction of the flap portion allows for easy transport to a construction site where the flap is assembled. Tubes have an inherent strength able to withstand considerable forces such as those from strong wave motion, particularly impact, torsion and buckling forces. However, the forces of the wave surge acting on a face of the flap portion tend to be increased, at the lines where the tubing sections abut, by a 'funnelling' effect of the curves of the tubing. Advantageously, where the tubes abut, a packing material is provided to reduce local wave impact forces. Preferably at least the upper part of the flap portion is provided with a resilient surface. The surface serves to absorb the energy of transient impacts, avoiding damage to the flap portion. For example, where the flap portion is comprised of large tubing sections, the tubing section may have a smaller diameter tubing, of a resilient material, wound spirally round it or slid on as a sleeve. This provides a compliant layer on the surface of the large tubes. A flap portion constructed of tubing sections also presents the possibility of ready adjustment of the buoyancy of the flap and thus of the biasing effect as discussed hereafter.

[0017] The height of the whole device, base portion and flap portion, is sized to suit the depth where the device is located, with the flap portion piercing the water, at least under calm conditions. To maximise capture of the available energy the height of the flap portion is generally slightly less than the overall height of the device. For example, where the device is 12m high the flap portion may be 10m high sited on a 2 m base. Power capture can be further improved by fitting a deflector plate to the base, which directs the wave motion towards the flap.

Preferably the flap portion has a width at least equal to its height. Power capture has been found to be dependent on the width of a flap portion, as described hereafter with reference to specific embodiments. More preferably the width of the flap portion is between 1 and 3 times the height of the flap portion. For the preferred water depth of 8 to 16m and the expected wave patterns in seas at these depths a width range of 10 to 30m gives relatively efficient energy capture, up to 80% for some wave periods and/or embodiments.

[0018] Preferably the flap portion has rounded or contoured top edge and/or side edges radiused in the range of from 0.5 to 2m, preferably 1 to 1.5m. As described hereafter with reference to specific embodiments, pro-

viding rounded side edges to the flap portion increases the power capture, by reducing the loss of power due to vortex shedding as waves move round the edges of a flap portion. Suitable contouring or curvature of the side edges of a given flap portion can readily be determined by suitable experimentation.

[0019] Existing known designs which utilise a seabed mounted base and a pivoting flap have focussed on a flap which remains substantially below the sea surface and the present invention leads in quite a different direction insofar as the flap portion is formed and arranged to pierce the water surface

[0020] The flap is positioned in the sea so that one of the faces of the plate faces directly into the prevailing direction of the waves at the chosen location. The wave pressure on the face of the flap portion causes a differential pressure and thereby causes it to oscillate back and forth about its pivots.

[0021] As discussed above it is preferred that the flap portion pierces the water surface with some freeboard available. As the flap portion is tilted by wave action from the vertical, the amount of the flap portion piercing the water surface (the freeboard) reduces. This can lead, depending on the size of the wave, to power being lost as part of the wave passes over the flap portion.

[0022] This effect can be mitigated by the provision of an additional structure at the top of the flap portion, which interacts more positively with waves at the surface even when the flap portion is tilted and freeboard reduced. For example the flap portion may have an additional substantially flat plate attached along its top edge, at right angles to the plane of the flap, to form a 'T', a closed 'Y' or an inverted 'L' shaped structure. In all cases it is preferred that these additional structures have rounded edges, for smooth flow of water over and around them.

[0023] Alternatively, the top portion of the flap may have an alternative shape, for example, the top edge of the flap may have a generally cylindrical form, of a diameter substantially greater than the general thickness of the flap portion. This arrangement is particularly preferred where the flap portion is of a modular form, constructed of a series of horizontally laid tubing sections. The top edge of the flap portion is simply constructed by adding a tubing section of a greater diameter to the top of the 'stack' of 'standard' tubing sections.

[0024] Other shapes may be envisaged, with the profile of the part of the flap portion that pierces the water being made to improve power capture when the flap portion is near the expected maximum tilt angle, in normal sea conditions.

[0025] As used herein the term 'relatively shallow waters' is intended to cover waters having a depth in the range of from 6 to 20 metres and thus it will be appreciated that for such an arrangement the device, that is the base portion and said flap portion may have a height slightly greater than the mean depth of the water in which the device is in use. Mean depth refers to the average depth between high and low tides where the device is in use in

tidal waters.

[0026] The flap portion of the device is biased towards the vertical, in order to provide a restoring force to the flap during its oscillation in response to wave action. The biasing of the flap portion also affects its natural oscillation period, which can affect the efficiency of power capture to a limited extent. The biasing of the flap portion towards the vertical is achieved by providing a flap portion which has a buoyancy sufficient to urge said flap portion to said generally vertical orientation with respect to said base portion. Thus in one arrangement of the invention said biasing means comprises said flap portion having substantial buoyancy. Conveniently the buoyancy of the flap portion is adjustable. This permits adjustment of the restoring force for the flap portion. The buoyancy can be provided in a flap portion by having chambers in the structure of the flap, which can be filled with air or other gas, or may be filled with a foam material. For example, where the flap portion comprises tubing sections the tube sections can be air filled, at least to some extent. Conveniently the buoyancy of the flap portion is adjusted by flooding or partial flooding of one or more air filled chambers.

[0027] The flap portion has a high centre of buoyancy and a low centre of mass. The upper portion of the flap undergoes the greatest motion in use, as it is furthest from the pivot, and so it has the greatest forces acting on it. By having a flap with a reduced mass (higher buoyancy) in its upper portion the bending forces acting on it are reduced. The desired properties may, for example, be achieved by providing a flap portion comprising horizontally stacked tubing sections with the diameter of the tubing used increasing towards the top of the flap. Flooding or partially flooding tubing near the base (pivot point) of the flap provides a low centre of mass whilst the larger diameter tubing near the top of the flap gives a large air volume to provide buoyancy centred towards the top of the flap.

[0028] Alternative or additional independent biasing means may be provided. For example, springs or torsion bars formed and arranged to urge said flap portion to a generally vertical orientation with respect to said base portion. The independent biasing means can be adjustable if required.

[0029] The distance from the flap portion's axis of pivoting to its centre of buoyancy and added moment of inertia will depend on the water depth. Numerical simulations and experiments have determined that it is extremely difficult to achieve a natural flap pitching period to match the incident wave period if the water depth is substantially greater than 20 metres.

It will be appreciated that the height of waves at any given point is not consistent throughout the year and at any one given time the incident wave period will differ. Thus to maximise the efficiency and performance of the device, the flap portion is formed and arranged to change its natural period. Thus preferably there is provided means for altering the centre of buoyancy of said flap portion; altering the buoyancy force; moving the centre of mass of the

flap portion with respect to said base portion; altering the centre of mass of the flap portion; and/or altering the characteristics of said biasing means.

[0030] Preferably to maximise the power capture the natural pitching period of the flap is adjusted to equal the dominant wave period of the incident wave. This may be achieved by one of the following means: -

- adjusting the mass of the flap by adding or removing ballast (typically water);
- adjusting the centre of mass of the flap by moving the height of an internal mass;
- adjusting the volume of the flap portion by inflation;
- or adjusting the stiffness of a biasing means, for example an elastomeric spring, or compressed gas (air spring) attached between the flap and the base portion or some other fixed point, such as the seabed.

[0031] Preferably to minimise loads on the device during extreme weather/wave events, and to facilitate maintenance, said flap portion is formed and arranged so that it may be laid more or less horizontal on the seabed (or the like). Preferably this functionality is achieved by flooding the flap with water so that it sinks to the seabed or driving the flap portion to the seabed and latching it into a fixed position.

[0032] Preferably to minimise potentially damaging loads during extreme weather/wave events the surface area of the flap portion can be reduced to minimise its coupling effect with an incident wave. This may be achieved by one of the following means: -

- the flap portion is inflatable and it can be deflated so as to reduce its size;
- a large portion of the flap's surface detaches in extreme events i.e. the flap portion is frangible or is designed to break, at a defined position, under extreme loading leaving the rest of the device undamaged;
- the upper portion of the flap, preferably the upper most portion which pierces the surface of the water in use of the device, is formed and arranged to be retractable into the flap portion during extreme weather/wave events. This arrangement prevents damage to said top portion.

[0033] One particular problem associated with prior art wave energy devices which are anchored to the seabed is that relatively substantial anchorage devices are required. In the present invention, and due to the relative buoyancy of the flap portion substantial anchorage systems of the type disclosed in the prior art are not required. Thus, preferably, there is provided anchorage means, desirably a self-attaching anchoring device, for quick attachment and release.

[0034] There may be provided a plurality of devices

according to the present invention, thus in another aspect the present invention provides an energy generating system comprising a plurality of wave energy conversion devices of the type described above and interconnected with each other.

[0035] To provide a smooth energy output from an array of wave energy conversion devices according to the present invention the flap portion of adjacent devices may be cascaded at an angle to the predominant wave direction so that the distance between the first and last flap is at least quarter a wavelength in the direction of wave propagation.

[0036] One significant problem though of existing designs is that maintenance costs are generally high due to the requirement to utilise heavy lifting gear for maintenance purposes. The present invention avoids or minimises such disadvantages by utilising components, in particular the flap portion, which are neutrally buoyant, thereby making them easy to handle. This may be achieved by utilising foam or other low density materials attached to the components of the device or introducing voids or chambers into the components which may be filled with air to increase buoyancy or filled with ballast (typically water) as required.

[0037] Advantageously to compensate for tide levels, both daily and throughout the year, the axis of rotation of the flap portion may be moved up and down with respect to the base portion. Thus the flap portion may be raised or lowered with respect to the sea bed when in use. Preferably the flap portion may be mounted on a support shaft which is itself held between two support portions that allow the flap portion and support shaft to move up and down (due to the flap portion's buoyancy) in response to variations in tide level. Alternatively the flap portion may be mounted on the support shaft which is mounted on actuators or other means which may be formed and arranged with control means to move the flap portion up or down according to tidal conditions. In all cases, where the flap portion can be moved up and down, the base portion and the flap portion continue to present a substantially continuous surface to the wave motion throughout the depth of the water. This can be arranged, for example by providing moveable deflector plates on the base portion, which rise as the flap portion is raised, to present a continuous surface of base portion deflector plate and flap portion to the wave motion.

[0038] Preferably said power extraction means utilises high pressure hydraulic fluid to drive a hydraulic motor, desirably a variable flow and speed hydraulic motor. The fluid is pressurised by the oscillation of the flap portion, preferably by means of a piston and cylinder driven by the flap portion, which pressurises the hydraulic fluid. The benefit of the variable flow and speed motor is that the flow can be continuously adjusted, preferably by computer control, to make the most efficient use of the power output of the flap portion. The computer control matches the operating parameters of the variable speed motor to the flow of hydraulic fluid, generated by the action of the

flap portion.

[0039] More preferably the power extraction means comprises a hydraulic motor, which is connected via a flywheel energy store to a variable speed electrical generator system. The variable speed electrical generator system may, for example, comprise a variable speed motor/induction generator, which is connected to an electrical grid system by a motor inverter and line rectifier. In use the output from the hydraulic motor is used to power the flywheel from which energy is extracted via the variable speed electrical generator system to supply electricity to the grid system. The flywheel is kept spinning in its optimum operating range by the controlled rate of power extraction. Preferably the control of the variable speed electrical generator system is via a computer control system.

[0040] Preferably the control of operation of the wave power generating device and its power extraction means is by a linked computer control system. The control system adjusts the operating parameters of the flap portion, the hydraulic motor, and the variable speed electrical generator system, to optimise the output of electrical power from the device in real time.

[0041] The computer control system monitors the operation of the flap portion, the hydraulic circuit that contains the hydraulic motor, the flywheel and the variable speed electrical generator system and adjusts parameters according to an appropriate algorithm.

[0042] Preferably the wave energy conversion device further comprises sensors, which determine the pattern and strength of waves before they strike the flap portion. These sensors allow adjustment of the parameters of the wave power generating device and power extraction means in a predictive fashion by said computer control system. The sensors may, for example, be positioned ahead of the flap portion.

[0043] The present invention also provides a method for extracting energy from waves comprising the steps of:

- a) providing a wave energy conversion device according to the invention;
- b) locating said device on the bed of a body of water with a depth of between 6 to 20m, with its flap portion facing the direction of waves;
- c) extracting wave energy from the waves in a said body of water.

[0044] Further preferred features and advantages of the present invention will now be described with reference to the accompanying drawings in which:-

Fig. 1 shows a schematic side elevation of a wave energy conversion device according to the present invention;

Fig. 2 shows a side view of an alternative arrangement of wave energy conversion device;

Fig. 3 is a front view of a further alternative arrangement;

Fig. 4 is a perspective view of a flap portion for use with the invention;

Fig. 5 is a schematic layout of a power takeoff system for use with the invention;

Figs. 6(a to c) show three embodiments of a device of the invention constructed from tubing sections.

Fig. 7 (a to d) shows a further embodiment of a device of the invention constructed from tubing sections.

[0045] A wave energy conversion device, generally indicated by reference no. 1, is shown in schematic form in Fig. 1 and comprises a base portion 2 which is anchored to the seabed 4 in a body of water 6. A flap portion 8 extends from said base portion 2 and is pivotally connected thereto and said flap portion 8 extends upwardly so as to pierce the surface 10 of the body of water in which the device is anchored. The flap portion 8 moves back and forward in an oscillating motion in response to wave 7 action thereon. The flap portion is mounted on the base portion on pivots 12 which allows the flap portion to hinge with respect to the base portion 2. In the embodiment shown the flap portion has a buoyancy such that the flap portion tends to be urged into a generally vertical orientation with respect to the base portion. There is provided a power extraction unit (not shown - see Fig. 5) for extracting the power generated by the movement of the flap portion in respect of wave action thereon. A deflector plate 13 is fitted at either side of the base portion to improve power capture from the incident wave energy by directing it onto the flap portion 8.

[0046] Turning to Fig. 2, which is generally similar to the arrangement shown in Fig. 1, the flap portion is provided with additional biasing means in the form of hydraulic springs 14 (shown schematically) which tend to urge the flap portion 8 to a generally vertical orientation with respect to the base portion 2.

[0047] Fig. 3 shows in a front view an alternative arrangement wherein there is used a torsion tube 16 which has resilient biasing characteristics and biases/urges said flap portion 8 to a generally vertical orientation with respect to the base portion 2. The torsion bar is located behind a deflector plate 13, (shown in dashed outline) on the base portion 2. This covers what would otherwise be a gap between the flap portion 8 and the base 2, leading to a loss of wave energy.

[0048] It will be noted that in both of the embodiments described above that there is a degree of 'free board', that being the portion of flap portion which extends above the surface of the water. Furthermore in each case the base portion 2 and the flap portion 8 have substantially no space in between, so that water does not flow through, resulting in a loss of power.

[0049] Fig. 4 is a perspective view of the profile of a flap portion 8 that may be used with the device in Figs. 1 or 2 and 3. The side edges 18 of the flap are radiused to reduce the effects of vortex shedding as a wave surges round the flap. The top portion of the flap 20 is also rounded.

[0050] Fig. 5, is a schematic illustration of a power take-off system for conversion of the oscillating motion of a wave energy conversion device of the invention to electricity.

[0051] The oscillating motion of the flap portion of a device of the invention (not shown in this figure but generally as shown in Fig. 1) is coupled by a suitable linkage (not shown) and a driving rod 21 to a hydraulic ram (piston) 22 which reciprocates in a cylinder 23 and is double acting. The cylinder 23 forms part of a hydraulic circuit 24 to which it is connected by an outlet point 26 at a discharge end 28 of the cylinder and an inlet port 30 at the opposite (inlet) end 32 of the cylinder 23.

[0052] A fluid flow passage 34 fitted with a non-return valve 36 allows hydraulic fluid 37, in the circuit 24, to flow through the ram 22 (piston) from the inlet end 32 of the cylinder to the discharge end 28.

[0053] In use as the ram 22 oscillates back and forth in the cylinder 23, hydraulic fluid is forced through the fluid flow passage 34 into the discharge end 28 of the cylinder during the closing stroke of the ram 22. On the opening stroke of the ram 22 the fluid cannot flow back through the fluid flow passage 34 because of the operation of the non-return valve 36 and so is pumped out of the outlet port 26 of the cylinder 23. The driving rod 21 has a cross sectional area that is half of the cross-sectional area of the cylinder 23. This means that the cross sectional area of the ram (piston) 22 facing the inlet end of the cylinder 23 is twice that facing the outlet end of the cylinder 23. Consequently the ram 22 is double acting and pumps the same volume of hydraulic fluid on both its opening and closing strokes. This pumping action pressurises the hydraulic fluid in the circuit 24.

[0054] The pressure in the hydraulic circuit 24, caused by the action of the ram in the cylinder is used to drive a variable displacement hydraulic motor 38 through which the fluid passes. Fluid used to drive the hydraulic motor then passes into a reservoir 40 where it is held available to be drawn back into the cylinder, via a second non-return valve 42 and the inlet port 30.

[0055] An accumulator 44, which is a pressure cylinder containing air 46, is connected to the pressure circuit between the cylinder 23 and the hydraulic motor 36. As fluid is pumped out of the cylinder into the hydraulic circuit the air 46 is compressed to store some of the pressure produced by the pumping action of the ram 22. This has the effect of smoothing variations in the pressure of the fluid entering the hydraulic motor 36, allowing more efficient operation.

[0056] The hydraulic motor 38 drives a flywheel 48 which stores energy from the hydraulic motor 38 until it is converted into electricity by an induction generator/motor 50 which connects to the flywheel. The output from the induction generator 50 is converted via a motor inverter 52 and line rectifier 54 into an electrical output 56 suitable for connection to an electricity grid (not shown). The induction generator/motor and its associated inverter and rectifier form a variable speed electrical generator

system which is used to keep the flywheel 48 spinning within its optimum range by extracting power from the flywheel in a controlled manner. The generator/motor is computer controlled to vary the extraction of energy from the flywheel in response to surges in the flywheel speed. To optimise the output from this system the hydraulic motor 38 is controlled by a computer control system 58. (Connections from the computer control system to the various elements of the generating system are not shown for reasons of clarity in the figure.) The computer control system 58 monitors inter alia ram velocity, hydraulic pressure and the rotational speed of the hydraulic motor in order to determine the optimal displacement for the motor at any given moment. The computer control system 58 also serves to tune the device to the prevailing wave period such that the force and angular velocity are in phase, depending on the sea characteristics as required.

[0057] Figure 6a shows a device of the invention 1, which has a 12m by 12m flap portion 8 attached by pivots 12 to a base portion 2, which is approximately 2m high. The flap portion consists of a horizontally stacked array of tubing sections 60 with diameters of 1.8m. The tubing sections 60 have 50mm spacings 62 between them, which are filled with a packing material 64. A driving rod 66 is pivotally attached to each side of the flap portion 8. These connect to pistons inside hydraulic cylinders 68 which are pivotally attached to the base portion 2. A deflector plate 70 fills the spacing between the bottom tubing section 72 of the flap portion 8 and the seabed 74. In use, when the flap portion 8 oscillates in response to wave action the driving rods 66 are driven to cause hydraulic fluid in the cylinders 68 to be pressurised by the action of the pistons (see fig.5). The pressurised fluid then flows out and returns via pipework connections 76 into the hydraulic circuit of rest of the power take off system (not shown, see Fig. 5 for example).

[0058] Figure 6b shows another embodiment of a device 1 of similar configuration to that of Fig. 6a except that curved end sections 78 ('end effectors') are located at each side edge 80 of the flap portion. In tests these end effectors 78 have been shown to improve power capture (see Test Results, below).

[0059] Figure 6c shows a yet further embodiment, which has the same configuration of that of Fig. 6b, but with the provision of additional tubing sections 82 located at the top of the flap portion. In use these provide additional buoyancy and the additional structure also gives more positive interaction with waves at the water surface when the flap portion 8 is tilted.

[0060] Figures 7 (a to d) show different views of a device of the invention 1 similar to that of Fig. 6a but with rounded side edges 18 and top portion 20.

[0061] Figure 7a shows the device 1 in perspective view, with the power take off or extraction means not shown apart from the driving rods 66 and hydraulic cylinders 68. Figure 7b shows the device 1 in front elevation, with a side elevation shown in Fig. 7c. A sectional side elevation, along the line XX shown in Fig. 7b is shown

as Fig. 7d.

[0062] In this embodiment the flap portion 8 is about 18m wide and the device 1 is of the order of 12m high to give particularly effective power capture at a water depth of up to 12m. The flap portion 8 is constructed of four horizontally disposed tubing sections 60, each of 1.8m diameter. The spacings 62 between each tubing section 60 are larger than those of the flap portion 8 of Fig. 6a, about 1m and are filled by curved plates 84. The required substantially continuous surface to be presented to the wave motion is completed by the curved deflector plates 70 fitted to the base portion 2.

Test results

[0063] Testing carried out using a model of a device 1 of the form shown in Figure 6a has demonstrated the substantial benefits of providing a device where the base portion and flap portion present a substantially continuous surface to the wave motion. The device 1 of figure 6a can show an improvement in power capture of about 36% when compared to a similar device where the spacings 62 between the tubing sections 60 are not filled and the deflector plate 70, which fills the space beneath the flap portion is not fitted.

[0064] Adding the curved end effectors 78 as in the device of Figure 6b gives a further improvement, which can be of the order of 16%, in power capture. Similarly the addition of tubing sections 82 as in Fig. 6c can add about a further 10% to the efficiency as measured by power capture.

[0065] The width of the flap portion in relation to its height has also been found to have a significant effect on the power capture. For example, for a device of the same general form of that shown in Figure 6b, the power capture factor in model tests was significantly decreased when the flap was 12m high by 6m wide when compared to the 12m by 12m flap. The testing was carried out using a wide range of sea states (sixteen) designed to be representative of the conditions expected along Pacific or Atlantic ocean coasts at the preferred depths for the invention. Increasing the flap width by 50%, from 12m to 18m, doubled the power output.

[0066] Various modifications may be made to the above described embodiments without departing from the scope of the present invention. Thus, for example, the device may be used in water desalination systems. Alternatively a plurality of devices may be used as a coastal defence system so as to reduce coastal erosion.

Claims

1. A wave energy conversion device (1), for use in relatively shallow water, comprising: a base portion (2) formed and arranged for anchoring to the bed of a body of water (6) in use of the device; an upstanding flap portion (3) pivotally connected (12) to said base

portion, said flap portion being formed and arranged to oscillate, in use, backwards and forwards about the vertical in response to wave motion acting on faces of the flap portion (8); and power extraction means for extracting energy from the movement of the flap portion; wherein said device (1) is formed and arranged so that when the base portion (2) is anchored to the bed of a body of water (6) with the flap portion (8) facing the wave motion, the base portion (2) and the flap portion (8) extend vertically through at least the entire depth of the water, to present a substantially continuous surface to the wave motion throughout the full depth of water from the wave crest to the sea bed, and said flap portion is sufficiently buoyant in water so as to be biased to the vertical in use, **characterised in that** said flap portion has a high centre of buoyancy and a low centre of mass.

2. A wave energy conversion device (1) according to claim 1 wherein the flap portion (8) and the base portion (2) are sized so that the flap portion (8) will pierce the water surface (10) at all expected tide levels and sea states.

3. A wave energy conversion device (1) according to claim 1 wherein the pivotal connection (12) of the flap portion (8) is moveable up and down with respect to the base portion (2).

4. A wave energy conversion device (1) according to any one of claims 1 to 3 wherein the flap portion (8) has a generally rectangular form.

5. A wave energy conversion device (1) according to any one of claims 1 to 4 wherein the flap portion (8) is of modular construction.

6. A wave energy conversion device (1) according to claim 5 wherein the modular components are selected from the group consisting of flat plates, composite reinforced flat plates and tubing.

7. A wave energy conversion device (1) according to any one of claims 1 to 6 wherein the flap portion (8) comprises tubing sections (92) arranged in a plane parallel and adjacent to each other to give a generally rectangular form to the flap.

8. A wave energy conversion device (1) according to claim 7 wherein the tubing sections (92) are arranged horizontally with larger diameter sections of tubing towards the top edge of the flap portion.

9. A wave energy conversion device (1) according to any preceding claim wherein at least the upper part of the flap portion (8) is provided with a resilient surface.

10. A wave energy conversion device (1) according to any preceding claim wherein the base portion (2) comprises a deflector plate (13) formed and arranged to direct the wave motion towards the flap portion (8).
11. A wave energy conversion device (1) according to any preceding claim wherein the flap portion (8) has a width at least equal to its height.
12. A wave energy conversion device (1) according to any one of claims 1 to 10 wherein the width of the flap portion (8) is between one and three times the height of the flap portion.
13. A wave energy conversion device (1) according to any preceding claim wherein the flap portion (8) has a rounded top or side edge (18).
14. A wave energy conversion device (1) according to claim 13 wherein the edge (18) is rounded in a radius of from 0.5 to 2m.
15. A wave energy conversion device (1) according to any preceding claim wherein the top edge of the flap portion (8) has a shape in cross section selected from the group consisting of cylindrical, a 'T', a closed 'Y' and an inverted 'L' shape.
16. A wave energy conversion device (1) according to any one of claims 1 to 14 wherein the top edge of the flap portion (8) has a generally cylindrical form in cross section and is of a diameter substantially greater than the general thickness of the flap portion.
17. A wave energy conversion device (1) according to any one of claims 1 to 16 wherein the flap portion (8) is provided with chambers which contain at least one of air, gas or a foam.
18. A wave energy conversion device (1) according to claim 17 wherein the buoyancy is adjustable by flooding an air filled chamber.
19. A wave energy conversion device (1) according to any one of claims 1 to 18 wherein additional biasing means selected from the group consisting of torsion bars (16), elastomeric springs (14) and compressed gas springs, are provided.
20. A wave energy conversion device (1) according to any preceding claim wherein the flap portion (8) is formed and arranged to change its natural period of oscillation by means selected from the group consisting of: altering the centre of buoyancy of said flap portion; altering the buoyancy force; moving the centre of mass of the flap portion with respect to said base portion; altering the centre of mass of the flap portion; and altering the characteristics of said biasing means.
21. A wave energy conversion device (1) according to any preceding claim wherein the flap portion (8) is formed and arranged so that it may be laid horizontal, in use, by means selected from the group consisting of: flooding the flap portion with water so that it sinks to the seabed; and, driving the flap portion to the seabed and latching it into a fixed position.
22. A wave energy conversion device (1) according to any preceding claim wherein the surface area of the flap portion (8) can be reduced by means selected from the group consisting of: providing a flap portion that is inflatable and can be deflated so as to reduce its size; providing a flap portion that is frangible; and providing a flap portion wherein the upper portion of the flap is formed and arranged to be retractable into the rest of the flap portion.
23. A wave energy conversion device according to any preceding claim wherein the power extraction means comprises: a hydraulic motor (38) driven by high pressure hydraulic fluid, a flywheel energy store (48) connected to said hydraulic motor; and a variable speed electrical generator (50) driven by said flywheel.
24. An energy generating system comprising a plurality of wave energy conversion devices (1) according to claim 1 and interconnected with each other.
25. An energy generating system according to claim 24 wherein the flap portions (8) of the plurality of devices are placed, in use, in an array with the flap portion of adjacent devices cascaded at an angle to the predominant wave direction so that the distance between the first and last flap is at least a quarter a wavelength in the direction of wave propagation.
26. A method for extracting energy from waves comprising the steps of: providing a wave energy conversion device (1) according to claim 1; locating said device on the bed of a body of water, with its flap portion (8) facing the direction of waves; and extracting wave energy from the waves in a said body of water.
27. A method for extracting energy from waves according to claim 26 wherein the wave energy conversion device (1) is located on the bed of a body of water with a depth of between 6 and 20m.
28. A method for extracting energy from waves according to claim 27 wherein the wave energy conversion device (1) is located on the bed of a body of water with a depth of between 8 and 16m.

Patentansprüche

1. Wellenenergieumwandlungsvorrichtung (1) für einen Einsatz in relativ flachem Wasser, die aufweist: einen Basisabschnitt (2), der für ein Verankern im Bett eines Gewässers (6) bei Benutzung der Vorrichtung ausgebildet und angeordnet ist; einen aufrecht stehenden Klappenabschnitt (8), der mit dem Basisabschnitt drehbar verbunden ist (12), wobei der Klappenabschnitt ausgebildet und angeordnet ist, um bei Benutzung rückwärts und vorwärts um die Vertikale als Reaktion auf die Wellenbewegung zu schwingen, die auf die Flächen des Klappenabschnittes (8) wirkt; und ein Energiegewinnungsmittel für das Gewinnen von Energie aus der Bewegung des Klappenabschnittes; wobei die Vorrichtung (1) so ausgebildet und angeordnet ist, dass, wenn der Basisabschnitt (2) im Bett eines Gewässers (6) verankert ist, wobei der Klappenabschnitt (8) zur Wellenbewegung hin liegt, sich der Basisabschnitt (2) und der Klappenabschnitt (8) vertikal durch mindestens die gesamte Tiefe des Wassers erstrecken, um eine im Wesentlichen kontinuierliche Fläche zur Wellenbewegung durchgängig über die vollständige Tiefe des Wassers vom Wellenberg bis zum Meeresboden zu verkörpern, und wobei der Klappenabschnitt im Wasser ausreichend schwimmfähig ist, um so bei Benutzung zur Vertikalen vorgespannt zu werden, **dadurch gekennzeichnet, dass** der Klappenabschnitt einen hohen Auftriebsmittelpunkt und einen niedrigen Schwerpunkt aufweist.
2. Wellenenergieumwandlungsvorrichtung (1) nach Anspruch 1, bei der der Klappenabschnitt (8) und der Basisabschnitt (2) so bemessen sind, dass der Klappenabschnitt (8) die Wasseroberfläche (10) bei allen erwarteten Gezeitenpegeln und Seegängen durchstoßen wird.
3. Wellenenergieumwandlungsvorrichtung (1) nach Anspruch 1, bei der die drehbare Verbindung (12) des Klappenabschnittes (8) mit Bezugnahme auf den Basisabschnitt (2) nach oben und nach unten beweglich ist.
4. Wellenenergieumwandlungsvorrichtung (1) nach einem der Ansprüche 1 bis 3, bei der der Klappenabschnitt (8) eine im Allgemeinen rechteckige Form aufweist.
5. Wellenenergieumwandlungsvorrichtung (1) nach einem der Ansprüche 1 bis 4, bei der der Klappenabschnitt (8) eine modulare Konstruktion aufweist.
6. Wellenenergieumwandlungsvorrichtung (1) nach Anspruch 5, bei der die Modulbauelemente aus der Gruppe ausgewählt werden, die besteht aus: flachen Platten; zusammengesetzten verstärkten flachen Platten; und Rohr.
7. Wellenenergieumwandlungsvorrichtung (1) nach einem der Ansprüche 1 bis 6, bei der der Klappenabschnitt (8) Rohrabschnitte (92) aufweist, die in einer Ebene parallel und benachbart zueinander angeordnet sind, um der Klappe eine im Allgemeinen rechteckige Form zu verleihen.
8. Wellenenergieumwandlungsvorrichtung (1) nach Anspruch 7, bei der die Rohrabschnitte (92) horizontal angeordnet sind, wobei die Abschnitte des Rohres mit größerem Durchmesser in Richtung des oberen Randes des Klappenabschnittes liegen.
9. Wellenenergieumwandlungsvorrichtung (1) nach einem der vorhergehenden Ansprüche, bei der mindestens der obere Teil des Klappenabschnittes (8) mit einer elastischen Fläche versehen ist.
10. Wellenenergieumwandlungsvorrichtung (1) nach einem der vorhergehenden Ansprüche, bei der der Basisabschnitt (2) eine Ablenkplatte (13) aufweist, die ausgebildet und angeordnet ist, um die Wellenbewegung in Richtung des Klappenabschnittes (8) zu lenken.
11. Wellenenergieumwandlungsvorrichtung (1) nach einem der vorhergehenden Ansprüche, bei der der Klappenabschnitt (8) eine Breite mindestens gleich seiner Höhe aufweist.
12. Wellenenergieumwandlungsvorrichtung (1) nach einem der Ansprüche 1 bis 10, bei der die Breite des Klappenabschnittes (8) zwischen dem 1- und 3-fachen der Höhe des Klappenabschnittes liegt.
13. Wellenenergieumwandlungsvorrichtung (1) nach einem der vorhergehenden Ansprüche, bei der der Klappenabschnitt (8) einen abgerundeten oberen oder Seitenrand (18) aufweist.
14. Wellenenergieumwandlungsvorrichtung (1) nach Anspruch 13, bei der der Rand (18) mit einem Radius von 0,5 bis 2 m abgerundet ist.
15. Wellenenergieumwandlungsvorrichtung (1) nach einem der vorhergehenden Ansprüche, bei der der obere Rand des Klappenabschnittes (8) eine Querschnittsform aufweist, die aus der Gruppe ausgewählt wird, die aus einer zylindrischen, einer "T"-, einer geschlossenen "Y"- und einer umgekehrten "L"-Form besteht.
16. Wellenenergieumwandlungsvorrichtung (1) nach einem der Ansprüche 1 bis 14, bei der der obere Rand des Klappenabschnittes (8) eine im Allgemeinen zylindrische Querschnittsform aufweist und einen

- Durchmesser zeigt, der im Wesentlichen größer ist als die übliche Dicke des Klappenabschnittes.
17. Wellenenergieumwandlungsvorrichtung (1) nach einem der Ansprüche 1 bis 16, bei der der Klappenabschnitt (8) mit Kammern versehen ist, die mindestens eines von Luft, Gas oder Schaumstoff enthalten. 5
18. Wellenenergieumwandlungsvorrichtung (1) nach Anspruch 17, bei der der Auftrieb durch Fluten einer luftgefüllten Kammer regulierbar ist. 10
19. Wellenenergieumwandlungsvorrichtung (1) nach einem der Ansprüche 1 bis 18, bei der ein zusätzliches Vorspannmittel bereitgestellt wird, die aus der Gruppe ausgewählt wird, die besteht aus: Torsionsstäben (16); elastomeren Federn (14); und Druckgasfedern. 15
20. Wellenenergieumwandlungsvorrichtung (1) nach einem der vorhergehenden Ansprüche, bei der der Klappenabschnitt (8) ausgebildet und angeordnet ist, um seine Eigenschwingungsdauer durch ein Mittel zu verändern, das aus der Gruppe ausgewählt wird, die besteht aus: Verändern des Auftriebsmittelpunktes des Klappenabschnittes; Verändern der Auftriebskraft; Bewegen des Schwerpunktes des Klappenabschnittes mit Bezugnahme auf den Basisabschnitt; Verändern des Schwerpunktes des Klappenabschnittes; und Verändern der Eigenschaften des Vorspannmittels. 20
25
30
21. Wellenenergieumwandlungsvorrichtung (1) nach einem der vorhergehenden Ansprüche, bei der der Klappenabschnitt (8) so ausgebildet und angeordnet ist, dass er bei Benutzung durch ein Mittel horizontal gelegt werden kann, das aus der Gruppe ausgewählt wird, die besteht aus: Fluten des Klappenabschnittes mit Wasser, so dass er auf den Meeresboden absinkt; und Treiben des Klappenabschnittes zum Meeresboden und Verriegeln dieses in einer stationären Position. 35
40
22. Wellenenergieumwandlungsvorrichtung (1) nach einem der vorhergehenden Ansprüche, bei der die Oberfläche des Klappenabschnittes (8) durch ein Mittel verringert werden kann, das aus der Gruppe ausgewählt wird, die besteht aus: Bereitstellen eines Klappenabschnittes, der aufblasbar ist und abgelassen werden kann, um so seine Größe zu reduzieren; Bereitstellen eines Klappenabschnittes, der zerbrechlich ist; und Bereitstellen eines Klappenabschnittes, bei dem der obere Teil der Klappe so ausgebildet und angeordnet ist, dass er in den restlichen Klappenabschnitt zurückgezogen werden kann. 45
50
55
23. Wellenenergieumwandlungsvorrichtung nach einem der vorhergehenden Ansprüche, bei der das
- Energiegewinnungsmittel aufweist: einen Hydraulikmotor (38), der mittels eines Hydraulikfluids mit hohem Druck angetrieben wird; einen Schwungradenergiespeicher (48), der mit dem Hydraulikmotor verbunden ist; und einen Stromerzeuger (50) mit veränderlicher Drehzahl, der mittels des Schwungrades angetrieben wird.
24. Energieerzeugungssystem, das eine Vielzahl von Wellenenergieumwandlungsvorrichtungen (1) nach Anspruch 1 aufweist, und die miteinander verbunden sind.
25. Energieerzeugungssystem nach Anspruch 24, bei dem die Klappenabschnitte (8) der Vielzahl der Vorrichtungen bei Benutzung in einer Anordnung angeordnet sind, bei der der Klappenabschnitt von benachbarten Vorrichtungen kaskadenförmig unter einem Winkel zur vorherrschenden Wellenrichtung so angeordnet ist, dass der Abstand zwischen der ersten und der letzten Klappe mindestens ein Viertel einer Wellenlänge in der Richtung der Wellenausbreitung beträgt.
26. Verfahren zur Gewinnung von Energie aus Wellen, das die folgenden Schritte aufweist: Bereitstellen einer Wellenenergieumwandlungsvorrichtung (1) nach Anspruch 1; Anordnen der Vorrichtung im Bett eines Gewässers, wobei ihr Klappenabschnitt (8) in Richtung der Wellen liegt; und Gewinnen von Wellenenergie aus den Wellen in einem Gewässer.
27. Verfahren zur Gewinnung von Energie aus Wellen nach Anspruch 26, bei dem die Wellenenergieumwandlungsvorrichtung (1) im Bett eines Gewässers mit einer Tiefe von zwischen 6 und 20 m angeordnet ist.
28. Verfahren zur Gewinnung von Energie aus Wellen nach Anspruch 27, bei dem die Wellenenergieumwandlungsvorrichtung (1) im Bett eines Gewässers mit einer Tiefe von zwischen 8 und 16 m angeordnet ist.

Revendications

1. Dispositif de conversion de l'énergie des vagues (1), destiné à être utilisé dans une eau relativement peu profonde, comprenant : une partie de base (2), formée et agencée de sorte à être ancrée sur le fond du plan d'eau (6) lors de l'utilisation du dispositif ; une partie de volet verticale (8), connectée de manière pivotante (12) à ladite partie de base, ladite partie de volet étant formée et agencée de sorte à osciller en service, vers l'arrière et vers l'avant autour de la verticale en réponse au mouvement des vagues agissant sur des faces de la partie de volet (8),

- et un moyen d'extraction de l'énergie pour extraire l'énergie à partir du déplacement de la partie de volet ; ledit dispositif (1) étant formé et agencé de sorte que lorsque la partie de base (2) est ancrée sur le fond du plan d'eau (6), la partie de volet (8) faisant face au mouvement des vagues, la partie de base (2) et la partie de volet (8) s'étendent verticalement à travers au moins l'ensemble de la profondeur de l'eau, pour présenter une surface pratiquement continue au mouvement des vagues à travers l'ensemble de la profondeur de l'eau, de la crête de la vague vers le fond de la mer, ladite partie de volet présentant une flottabilité suffisante dans l'eau pour être poussée vers la verticale en service, **caractérisé en ce que** ladite partie de volet présente un centre de flottabilité élevé et un centre de masse peu élevé.
2. Dispositif de conversion de l'énergie des vagues (1) selon la revendication 1, dans lequel la partie de volet (8) et la partie de base (2) sont dimensionnées de sorte que la partie de volet (8) perce la surface de l'eau en présence de tous les niveaux de marée et des états de la mer possibles.
 3. Dispositif de conversion de l'énergie des vagues (1) selon la revendication 1, dans lequel la connexion pivotante (12) de la partie de volet (8) peut être déplacée vers le haut et vers le bas par rapport à la partie de base (2).
 4. Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications 1 à 3, dans lequel la partie de volet (8) a une forme généralement rectangulaire.
 5. Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications 1 à 4, dans lequel la partie de volet (8) a une construction modulaire.
 6. Dispositif de conversion de l'énergie des vagues (1) selon la revendication 5, dans lequel les composants modulaires sont sélectionnés dans le groupe constitué de plaques plates, de plaques plates renforcée d'un composite et de tubages.
 7. Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications 1 à 6, dans lequel la partie de volet (8) comprend des parties de tubes (92) agencées dans un plan parallèle et adjacent les unes aux autres pour conférer une forme généralement rectangulaire au volet.
 8. Dispositif de conversion de l'énergie des vagues (1) selon la revendication 7, dans lequel les sections de tubes (92) sont agencées horizontalement, les sections de tubes à diamètre accru étant agencées vers le bord supérieur de la partie de volet.
 9. Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications précédentes, dans lequel au moins la partie supérieure de la partie de volet (8) comporte une surface élastique.
 10. Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications précédentes, dans lequel la partie de base (2) comprend une plaque de déflexion (13), formée et agencée de sorte à diriger le mouvement des vagues vers la partie de volet (8).
 11. Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications précédentes, dans lequel la partie de volet (8) a une largeur au moins égale à sa hauteur.
 12. Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications 1 à 10, dans lequel la largeur de la partie de volet (8) représente entre une et trois fois la hauteur de la partie de volet.
 13. Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications précédentes, dans lequel la partie de volet (8) comporte une partie supérieure arrondie ou un bord latéral arrondi (18).
 14. Dispositif de conversion de l'énergie des vagues (1) selon la revendication 13, dans lequel le bord (18) est arrondi à un rayon compris entre 0,5 et 2 m.
 15. Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications précédentes, dans lequel le bord supérieur de la partie de volet (8) a une forme de section transversale sélectionnée dans le groupe constitué d'une forme cylindrique, d'une forme en T, d'une forme en Y fermé et d'une forme en L inversé.
 16. Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications 1 à 14, dans lequel le bord supérieur de la partie de volet (8) a une section transversale de forme généralement cylindrique et a un diamètre notablement supérieur à l'épaisseur générale de la partie de volet.
 17. Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications 1 à 16, dans lequel la partie de volet (8) comporte des chambres contenant au moins une substance, de l'air, du gaz ou une mousse.
 18. Dispositif de conversion de l'énergie des vagues (1) selon la revendication 17, dans lequel la flottabilité

peut être ajustée par noyage d'une chambre remplie d'air.

- 19.** Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications 1 à 18, comportant des moyens de poussée additionnels sélectionnés dans la groupe constitué de barres de torsion (16), de ressorts élastomères (14) et de ressorts à gaz comprimé. 5
- 20.** Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications précédentes, dans lequel la partie de volet (8) est formée et agencée de sorte à changer sa période d'oscillation naturelle par un moyen sélectionné dans le groupe constitué de : un changement du centre de flottabilité de ladite partie de volet ; un changement de la force de flottabilité ; un déplacement du centre de masse de la partie de volet par rapport à ladite partie de base : un changement du centre de masse de la partie de volet ; et un changement des caractéristiques dudit moyen de poussée. 10
- 21.** Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications précédentes, dans lequel la partie de volet (8) est formée et agencée de sorte à pouvoir être placée horizontalement en service par l'intermédiaire d'un moyen sélectionné dans le groupe constitué de : un noyage de la partie de volet avec de l'eau, de sorte qu'elle s'abaisse vers le fond de la mer ; et un entraînement de la partie de volet vers le fond de la mer et son verrouillage dans une position fixe. 20
- 22.** Dispositif de conversion de l'énergie des vagues (1) selon l'une quelconque des revendications précédentes, dans lequel l'aire de surface de la partie de volet (8) peut être réduite par un moyen sélectionné dans le groupe constitué de : la fourniture d'une partie de volet gonflable et pouvant être dégonflée de sorte à réduire sa taille ; la fourniture d'une partie de volet frangible ; et la fourniture d'une partie de volet dans laquelle la partie supérieure du volet est formée et agencée de sorte à pouvoir être rétractée dans la partie restante de la partie de volet 25
- 23.** Dispositif de conversion de l'énergie des vagues selon l'une quelconque des revendications précédentes, dans lequel le moyen d'extraction de l'énergie comprend : un moteur hydraulique (38) entraîné par un fluide hydraulique haute pression ; un stockage d'énergie dans des volants d'inertie (49) connecté audit moteur hydraulique ; et un générateur électrique à vitesse variable (50) entraîné par ledit volant d'inertie. 30
- 24.** Système de production d'énergie, comprenant plusieurs dispositifs de conversion d'énergie des vagues (1) selon la revendication 1, connectés les uns aux autres. 35
- 25.** Système de production d'énergie selon la revendication 24, dans lequel les parties de volet (8) des plusieurs dispositifs sont placés en service dans un agencement dans lequel la partie de volet de dispositifs adjacents est montée en cascade à un angle par rapport à la direction prédominante des vagues, de sorte que la distance ente le premier et le dernier volet représente au moins un quart d'une longueur de la vague dans la direction de la propagation des vagues. 40
- 26.** Procédé d'extraction d'énergie de vagues, comprenant les étapes ci-dessous : fourniture d'un dispositif de conversion de l'énergie des vagues (1) selon la revendication 1, positionnement dudit dispositif sur le fond d'un plan d'eau, sa partie de volet (8) faisant face à la direction des vagues ; et extraction de l'énergie des vagues dans un dit plan d'eau. 45
- 27.** Procédé d'extraction d'énergie des vagues selon la revendication 26, dans lequel le dispositif de conversion de l'énergie des vagues (1) est agencé sur le fond d'un plan d'eau ayant une profondeur comprise entre 6 et 20 m. 50
- 28.** Procédé d'extraction d'énergie des vagues selon la revendication 27, dans lequel le dispositif de conversion de l'énergie des vagues (1) est agencé sur le fond d'un plan d'eau ayant une profondeur comprise entre 8 et 16 m. 55

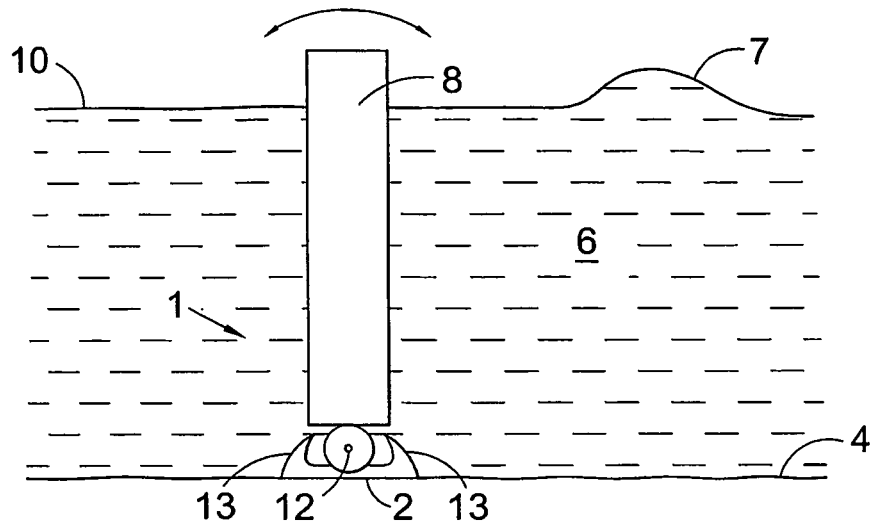


Fig. 1

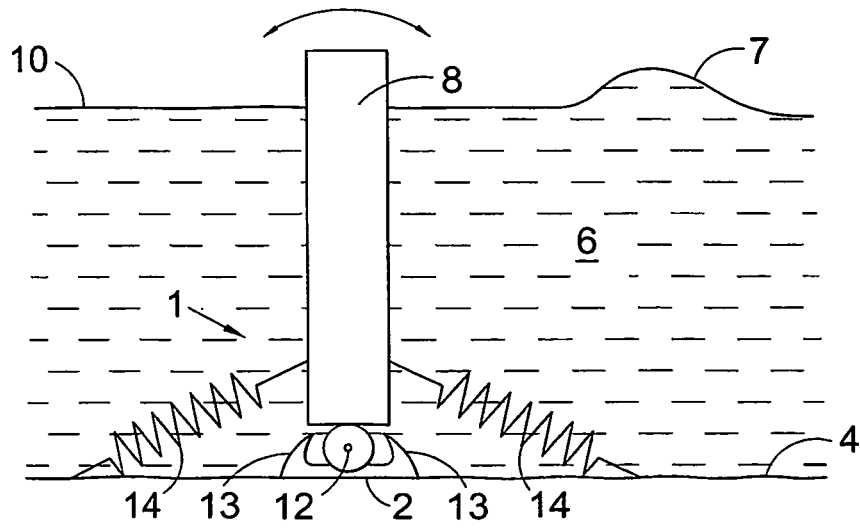


Fig. 2

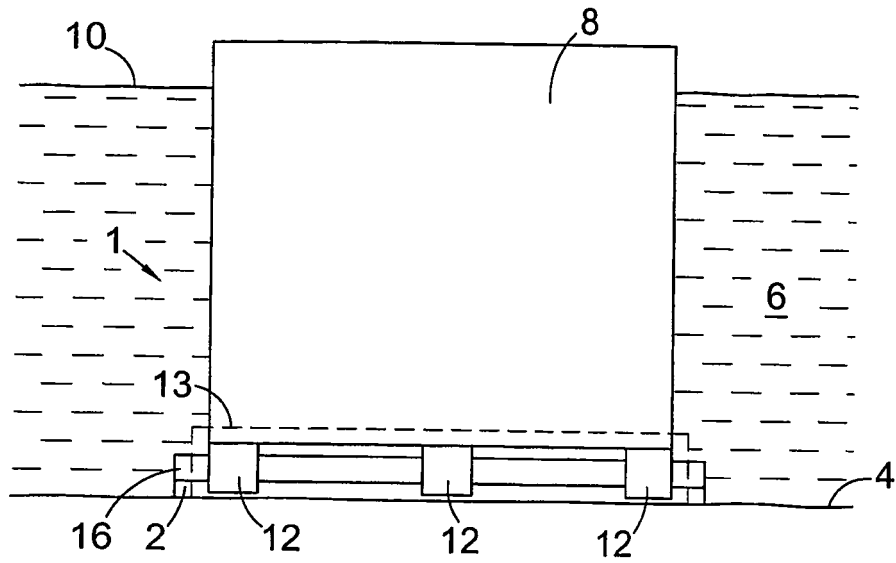


Fig. 3

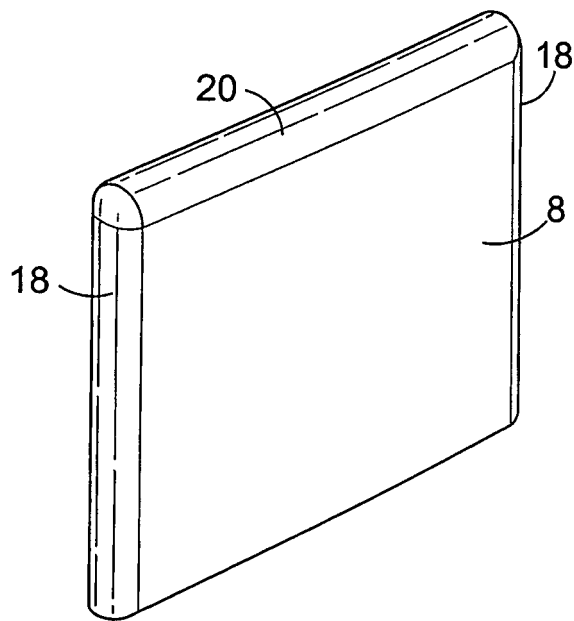


Fig. 4

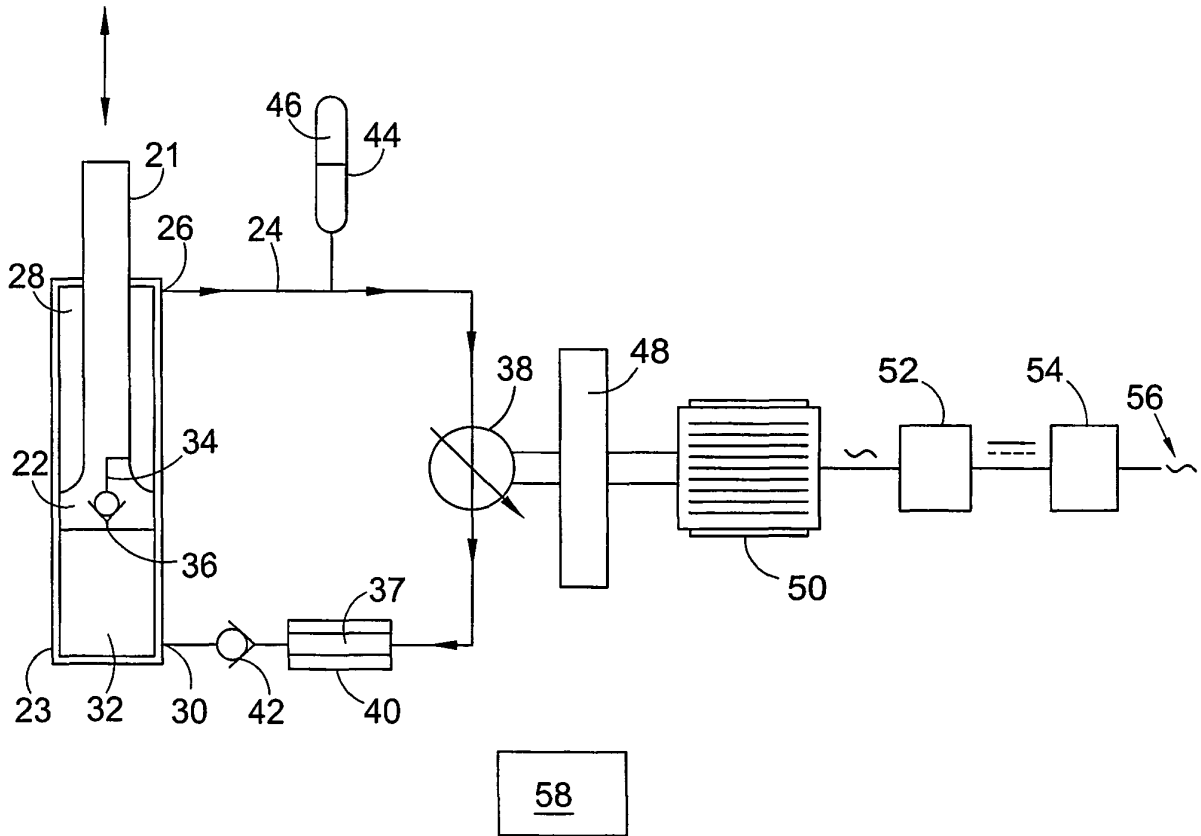


Fig. 5

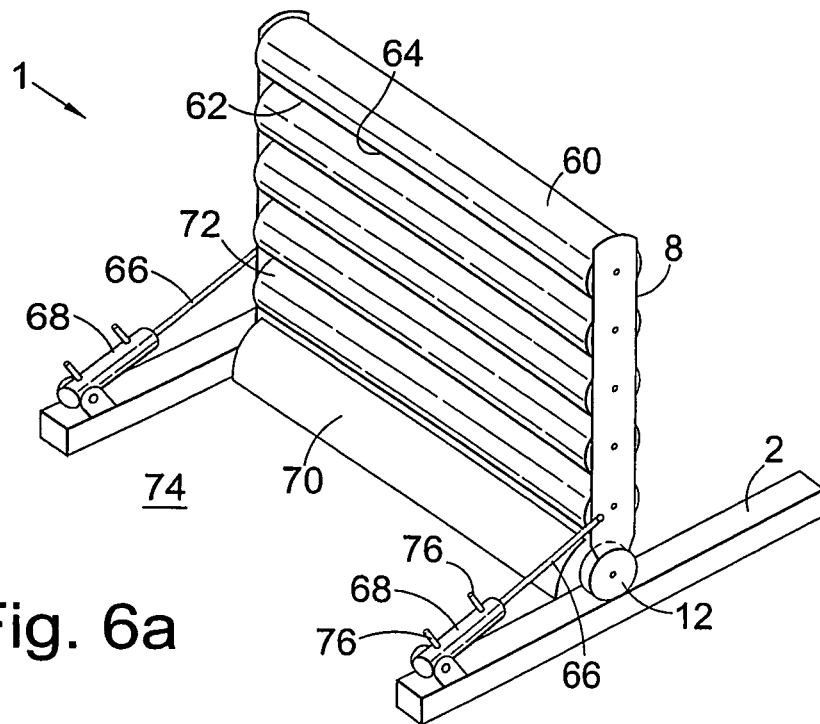


Fig. 6a

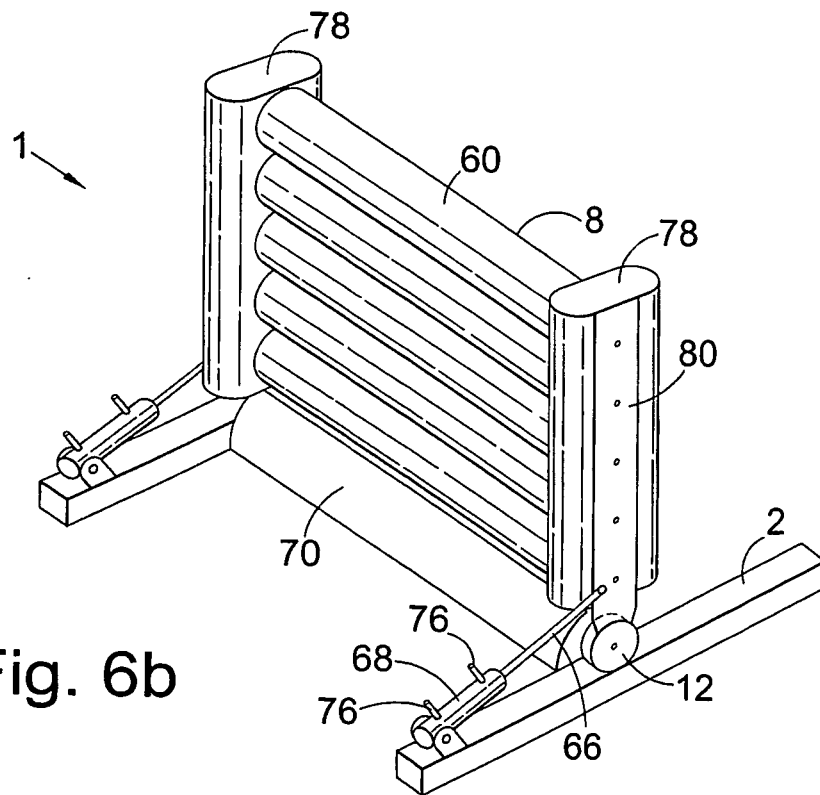


Fig. 6b

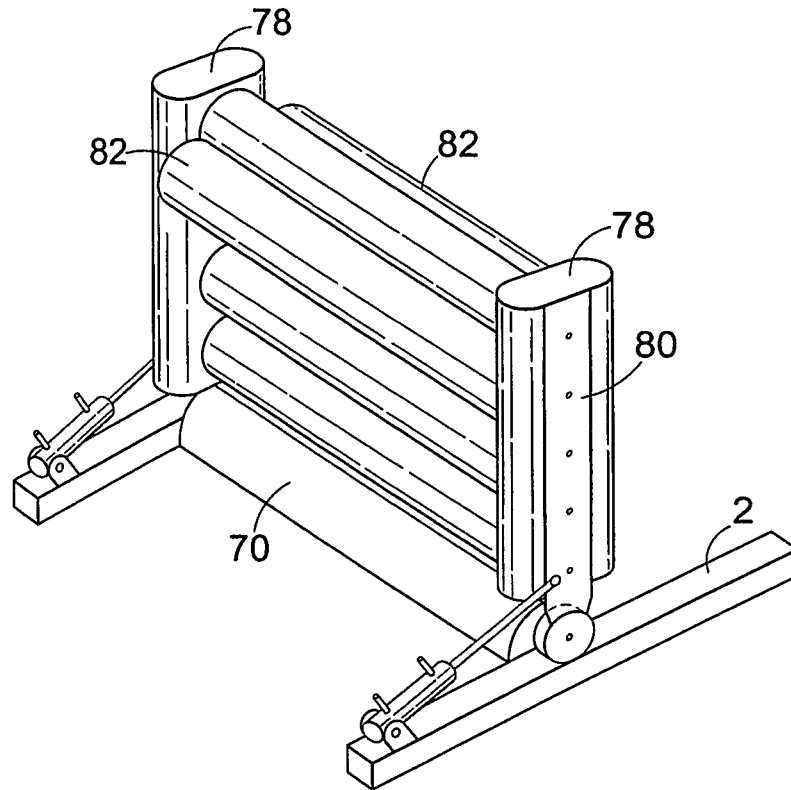


Fig. 6c

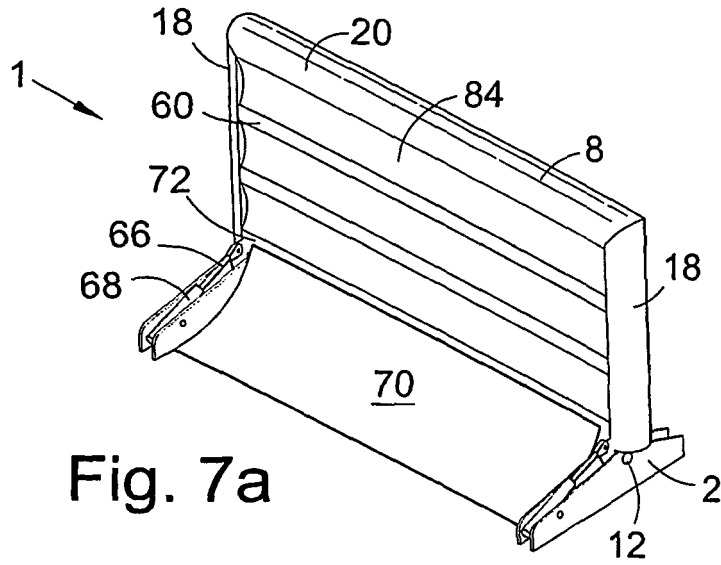


Fig. 7a

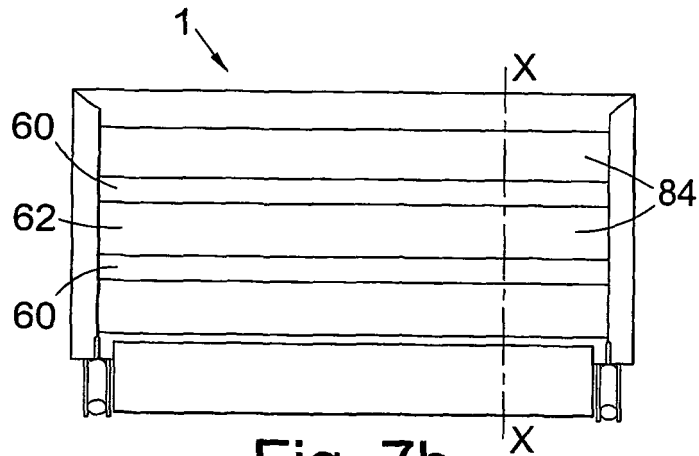


Fig. 7b

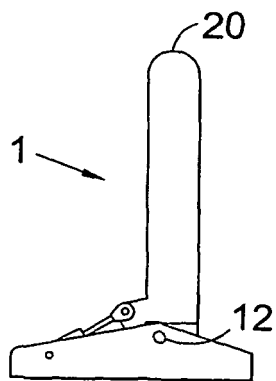


Fig. 7c

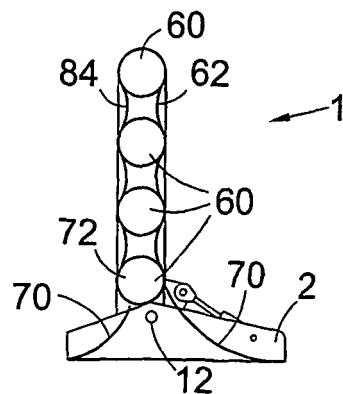


Fig. 7d

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 4580400 A [0003]
- WO 2004007953 A1 [0003]
- WO 03036081 A [0003]
- WO 9817911 A [0003]
- US 4371788 A [0004]
- JP 04358769 B [0004]